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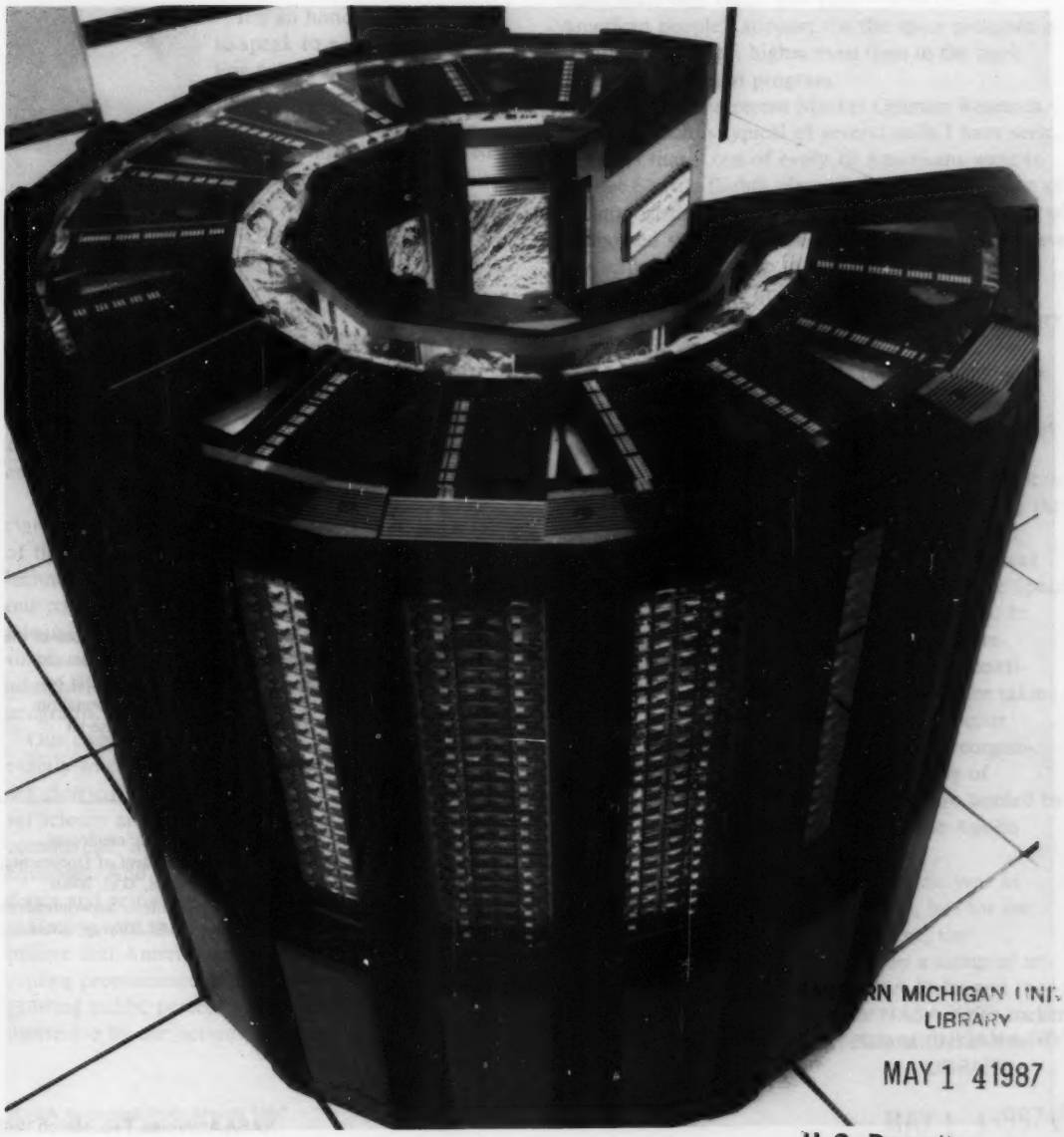

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About the Cover

Pictured on the cover is the 4-foot high, c-shaped Cray-2 supercomputer at NASA Ames. The Cray-2 does a quarter billion computations per second and has an enormous 256 million word internal memory—16 times larger than those of previous supercomputers.

The Cray-2 is part of the Numerical Aerodynamic Simulator (NAS), the most powerful supercomputer system in the world. The NAS system will be used to solve complex equations that predict the pattern of airflow around proposed aircraft designs. It also will be used for research in weather modeling, computational chemistry and computational astrophysics. More on page 6.

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Administrator's Column

(In this column NASA Activities features an article by NASA Administrator Dr. James C. Fletcher. These articles focus on subjects that address topics of broad interest to the agency's employees. This column features a speech presented at the National Security Industrial Association West Coast dinner, Los Angeles, California)

It's an honor and privilege to speak to you this evening. For nearly 44 years — during some of the most crucial turning points in our history — your organization has played a vital role in keeping America strong and in fostering policies and programs for peace in the world.

Today, after nearly three decades of space operations and a year after the Challenger accident, the United States stands at still another turning point, one that is crucial for the future of our civil space program. It is clear that we must blaze new paths if we are to retain our leadership there, a leadership many claim is already eroding.

There is a good deal of evidence to support that claim. It includes our 2-year down-time in the wake of the Challenger accident, our eroding aerospace technology base, the fact that public expectation of our continued preeminence has not been backed by adequate resources, and of course, the growing and sustained commitments of both our friends and our adversaries to their own respective national space programs.

Our competitors do indeed, appear to know exactly where they want to go in space, their goals are clear-cut. They include expanded access, self-sufficiency and increased opportunities for scientific, commercial, industrial and national security advances. And, as we all know, they have the confidence and resources to forge ahead.

Having said that, let me add that those of us who believe that America's future is linked to our continuing preeminence in space are heartened by the growing public perception that the future is ours to determine by our actions and our choices.

We are fortunate to have in President Reagan a leader who acts on his belief that a strong America requires a strong space program across the board — in both the military and civil arenas.

The President has made clear through his Strategic Defense Initiative that advances in space technology for defensive purposes offer a real opportunity for peace in the world. His support for a new orbiter to replace Challenger, for the Space Station and for the National Aerospace Plane research program offers additional evidence of his faith in our future in space.

There is good reason to believe that most Americans share that faith. The polls tell us that the American people's support for the space program is at an all-time high, higher even than in the peak years of the Apollo program.

For example, a recent Market Opinion Research Survey, which is typical of several polls I have seen, indicates that 9 out of every 10 Americans want to resume Shuttle flights, despite the risks. Eight out of 10 support the Space Station and the continuation of unmanned space exploration. Seven out of 10 believe it is important to keep the United States ahead of the Soviets in space and six out of ten Americans want our government to spend whatever is necessary to maintain our leadership in space.

NASA has rededicated itself to giving the people the kind of space program Americans deserve, expect and can be proud of. We are fixing the Shuttle. We have scheduled our first post-Challenger flight for February 18, 1988, but will fly only if it is safe to fly. We are totally dedicated to returning the nation to safe and reliable spaceflight.

To meet that goal we have restructured the way we manage our major programs, including the Space Transportation System and the Space Station. In addition, I announcd a major management reorganization of the entire agency, and am confident that the steps we have taken and will be taking will not only strengthen NASA, but will better prepare it for the challenges ahead. The reorganization grew out of a comprehensive study of NASA's management structure by a team headed by General Sam Phillips, who managed the Apollo program.

As we all know, 1986 was a traumatic year in space, not only for the United States, but for our European allies as well. Here at home, the Challenger accident was followed by a string of unsuccessful ELV launches: the NASA Delta and the Air Force Titan in May, and the NASA Aries rocket in August. Meanwhile, ESA's Ariane rocket was

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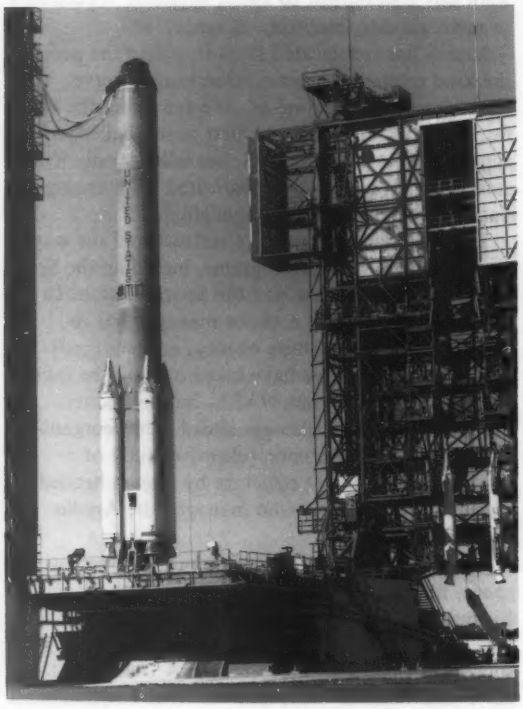
grounded following a launch failure in May, during which the spacecraft's third stage failed to ignite properly.

For a while, it appeared as if all of these failures were a coincidence beyond belief, and that skullduggery must have been involved. But we known now that, distressing as this situation was for all of us, those accidents were an unhappy coincidence.

Today, a new spirit of dedication and motivation is driving the NASA team. We have shaken off our complacency — and I would be the first to admit that we had become complacent. We are moving out from the shadow of Challenger and are getting the space program back on track. Fortunately for our country, it's not a moment too soon.

In September, we launched a Delta, an Aries and an Atlas E rocket. In November, we launched a Scout rocket and in December an Atlas-Centaur rocket. All of these missions were successful. And I would point out that four out of the five launched essential payloads for the Department of Defense. When the Shuttle begins to fly again, the DOD will be a prime user, as was intended, since the Shuttle was meant to serve all Americans.

One of the lessons of the Challenger accident is



Delta 179 is ready to carry the Goes-H weather satellite into orbit

that this nation cannot afford to depend solely on any one type of launch vehicle — even the multi-purpose Shuttle — if it is to have assured access to space. It is pretty clear at this point that the nation needs a mixed fleet, including the Shuttle and ELVs, to maintain that access, which is essential to our national security, economic well-being and leadership in the world.

NASA has adopted a policy to support the mixed fleet concept. We have done so because it is vital that our nation has continuous launch capability and adequate capacity.

Having said that, I want to stress another aspect of NASA policy. It is the agency's strong and continuing commitment to use the Shuttle for appropriate missions, including missions to foster science, commerce, international cooperation, and of course, our own national security.

We at NASA will continue to work to facilitate cooperation with the DOD and other users and potential users on both the Shuttle and the Space Station.

For DOD, we will ensure that vital national security payloads are launched successfully, that joint NASA/DOD programs, such as the National Aerospace Plane Research program, are productive and that NASA research facilities and the work performed at them continue to be made available to the military.

Indeed, our legislative mandate requires that we do all that and more. The fact that we take that mandate seriously and will continue to do all we can to help assure the security of the United States, does not mean, however, that NASA is becoming or ever will become militarized.

That will not happen on my watch, nor do I believe will it happen on the watch of any future NASA Administrator.

The reason why is very simple. That is not our role. As you know, we are charged with preserving United States leadership in space and aeronautics for peaceful purposes for the benefit of mankind. And that is what we will continue to do.

NASA has viewed this 2-year down-time not only as an opportunity to rebuild and reshape the agency to meet future challenges, but also as an opportunity to define what those challenges ought to be.

We recently began an effort to define the goals, objectives and program thrusts to guide the future of the nation's civil space program.

The first steps were taken in October, when NASA's Strategic Planning Council revised NASA's broad goals.

Those goals now are: to advance scientific knowledge of the planet Earth, the solar system and the universe beyond, to expand human presence beyond the Earth into the solar system and to strengthen aeronautics research and develop technology toward promoting United States leadership in civil and military aviation.

The next step in this process will be to define specific objectives to achieve each of these goals. Then we will identify the program thrusts required to achieve our goals and objectives.

This will be a thorough and creative process. It will not be accomplished overnight or in the next few weeks or even in the next few months. But we are confident that, in the end, our work will produce a vital and comprehensive blueprint to guide the United States to a position of long-term leadership among spacefaring nations through the end of the century and beyond.

Clearly the nation needs such a blueprint and the public deserves and expects one.

I would like to expand briefly on the second goal for a moment. It is an historic goal, because it marks the first time NASA is committing itself to work to expand the human presence into the solar system.

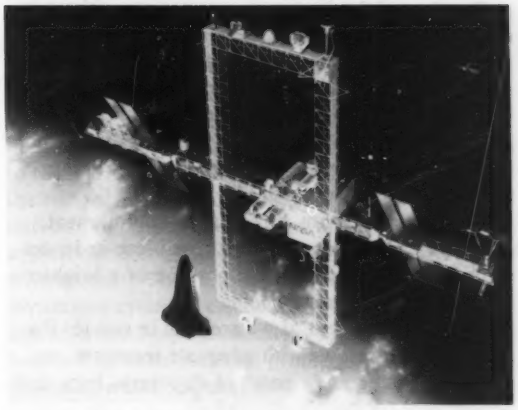
The Apollo program, of course, began this process. It demonstrated beyond a doubt, that with a sustained national commitment of will and resources, this nation could do the seemingly impossible.

Apollo made us visitors to space. The Space Station will transform us into permanent residents.

There are three other critical points I would make about the Space Station. First, it will be essential in securing our leadership in space through the end of the decade and in the early years of the 21st century. Second, the Station is a key element in recovering our national loss of momentum after the Challenger accident. And finally, the Space Station will be the central focus of all our efforts to expand commerce, industry and science in space for decades to come.

The Space Station and the automated vehicles that we will build to extend our reach within and between orbits, will be the key to our future in space. With the Station and its infrastructure, we will have a transportation node and gateway to the solar system. From an expanded Space Station, we can construct Orbital Service Stations. On these Stations, spacecraft destined for other points in the solar system can be built, launched, maintained and refueled.

So, the Space Station clearly is a vital and necessary step in expanding the human presence



A Shuttle prepares to berth at the permanently manned Space Station hovering 300 miles above the Earth in this artist concept

beyond our planet and into the solar system. But where should we be going beyond the Space Station?

That limitless horizon out there offers an exciting range of options. Some could take us to the asteroids or to the Moon to mine their resources, and even, perhaps to establish a permanent commercial and scientific lunar base. Alternately, one option would be a first human visit to the planet Mars, to be followed eventually by the establishment of a permanent base there, as well.

As you know, the National Commission on Space has outlined a bold and visionary program for the United States in space over the next 50 years. The Commission envisions a manned outpost on the Moon by the year 2005 and the first manned mission to Mars by the year 2015.

To some, those goals may seem overly ambitious. My answer to that is if we were to propose today a 28-year space program that includes all that we have done over the past 28 years, many would find it incredible. Yet we have done it all. In less than a generation we have learned more about our Earth, the solar system and the universe than was known in all previous history.

Today, within the context of our revised goals, NASA is looking beyond the Space Station at what this nation's next major steps in space should be. We have begun a major planning effort to identify the required technology and required program thrusts for the next decade.

I have asked Dr. Sally Ride to shepherd this effort. She is developing a report to be called "Space '95," which will identify what we need to do to build the foundations of a revitalized United States space program to ensure our leadership in space.

Clearly such leadership does not come without its costs. Whether the United States builds a stage-by-stage "bridge to space", as the Paine Commission envisions, or whether we expand our presence there by Ferry boat, one thing is clear: this nation cannot afford to delay much longer in renewing its commitment to a long-term expansionary space program with clear-cut and well-defined goals.

If America does not make such a commitment, and soon, our nation could very well lose its leadership in space, and with it the promise of a brighter future for generations to come.

But if we persevere, if we are firm in our resolve and back that resolve with adequate resources, we can and will open new paths of discovery, hope and opportunity for people everywhere.

Fifty-three years ago, President Franklin Delano Roosevelt borrowed a line from the Book of Proverbs in the Old Testament to remind our nation, "Where there is no vision, the people perish." At this critical turning point in our civil space program, I am confident Americans have the vision to move forward.

For we are, above all, a nation that is never finished, a nation in which each generation renews America by building on what went before.

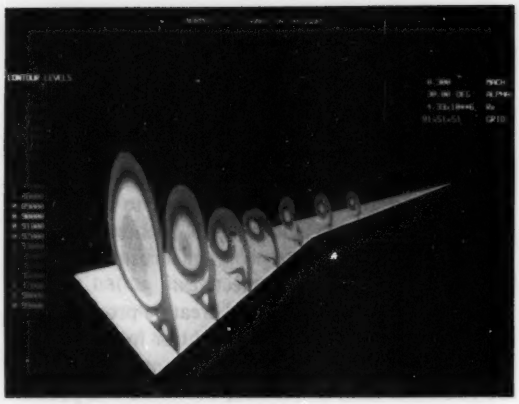
Now it is our generation's turn. And if the past is any guide, nothing will stop us.

NASA Powerful Super-Computer System Goes Operational

NASA's numerical aerodynamic simulation (NAS) computer system, considered the world's most powerful computing system, is operational.

Dedication ceremonies took place on March 9 at the NAS site, NASA's Ames Research Center, Mountain View, Calif. Other events included a symposium on the future implications of super-computer systems for society, tours and illustrations of system capabilities. An air show also took place.

NAS will be used for pioneering research in aeronautics. This includes work on the National Aero-Space Plane Program, a joint DOD/NASA program to validate a wide range of aerospace vehicle technologies and capabilities including horizontal takeoff and landing, single-stage operation to orbital speeds and sustained hypersonic cruise within the atmosphere using airbreathing propulsion. A wide



A Cray-2 simulation of pressure contour plots over a double delta wing

variety of future operational aerospace vehicles may be possible as a result of this technology development and validation program, ranging from space launch vehicles to long-range air defense interceptors and hypersonic transports.

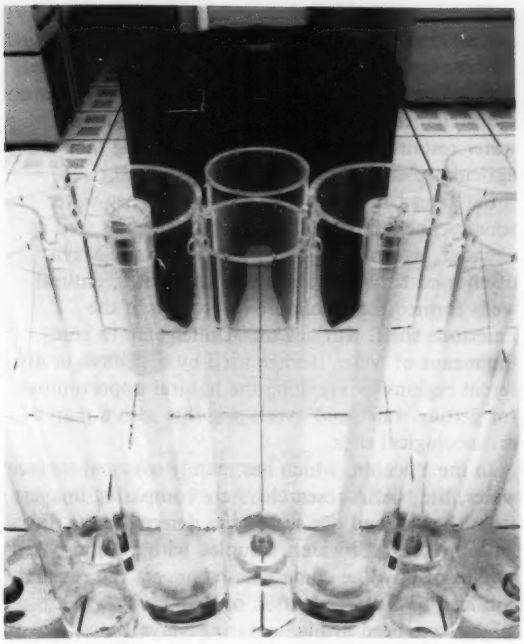
The NAS system will help ensure continued national preeminence in aeronautical research. It will allow major steps toward simulating actual aircraft flight in a computer, making possible important advances in aircraft design — reducing cost and increasing performance. NAS will serve as a pathfinder capability in supercomputing for government, universities and industry and will encourage development of improved supercomputers.

NAS also will be used for computational chemistry, weather modeling, astrophysics applications and genetics research.

Project officials emphasize that NAS is not a set of computer hardware, but an evolving capability. NAS is an array of people, skills, powerful central processors, a nation-wide communications network and a range of computation, scheduling and output devices.

The operational system will be capable of a quarter of a billion computations per second. This speed will be increased to a billion calculations per second with acquisition of a second high-speed processor this year and to 10 billion calculations per second within a decade.

The NAS system is presently driven by the Cray 2 supercomputer, which has an enormous 256 million word internal memory, 16 times larger than those of previous supercomputers. Planners for NAS expect to have the two fastest supercomputers available as central computing engines for the system. As a faster processor is developed by industry and becomes



The Cray-2 is pictured behind the plexiglass reservoirs for the inert fluorcarbon liquid used to cool the machine. The coolant is the same fluid used by hospitals as an artificial plasma to replace human blood

available, it will be acquired and the slower of the two current central supercomputers will be retired.

A national network will allow off-site scientists, at 27 locations, access to the system via satellite or high-speed terrestrial lines. More than 250 scientists and engineers will be using the system.

The NAS building is equipped with an array of systems for the optimal functioning of the computers. The 90,000-square-foot structure has a 14,000-square-foot central computer room, bronzed windows which dim entering sunlight and a climate cooling system 28 times more powerful than in a normal office building of the same size.

Space Technology Brings New Findings On Ancient Maya

Satellite images of Mexico's Yucatan Peninsula, Central Guatemala and Belize have led to new discoveries about ancient Maya settlement patterns, environmental setting and natural resource use. NASA scientists have found evidence of an ancient river plain, sea level changes and tectonic fault lines, which may have been important geographic elements in shaping the ancient Maya civilization.

Investigators at NASA's Ames Research Center, Mountain View, Calif., also are using the satellite imagery to detect Maya water sources, such as natural wells and ponds, and compare their locations to those of ancient Maya ruins. Investigators believe the remote sensing project will help resolve a central question in Maya studies — how the Maya built a sophisticated civilization in a relatively resource-poor environment? They also hope to understand the mysterious cycles of expansion and decline that characterized Maya civilization. Many scholars believe that environmental problems, including misuse of resources, may have led to the periods of decline. The Maya civilization, noted for elaborate temples, advanced mathematics and astronomy and large-scale agriculture, spread across Central America from 2000 BC until the Spanish conquest in the 16th Century.

"Environmental problems resembling today's problems were experienced long ago, on a smaller scale by the Mayas and other ancient people," said Ames project chief Charles Duller. "By studying the Maya, we can better understand human interaction with the Earth system: how they adapted to the environment and its changes, and what changes they may have caused.

While remote sensing has been widely used to search for archaeological sites, the Ames project is among the first to use space technology to attempt to understand an ancient civilization by studying its environment. "In combining remote sensing, environmental studies and archaeology, this is a pioneering effort," Duller says.

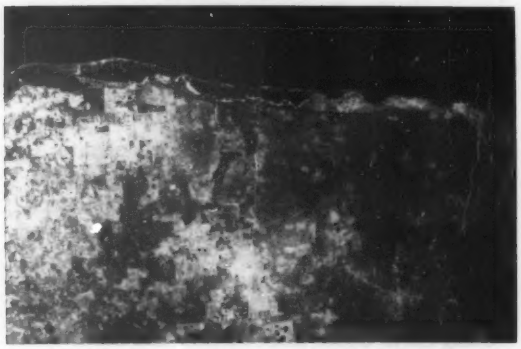
Using Earth Observation Satellite and Earth Resources Observation Systems imagery from the Landsat 5 satellite, which has an advanced multispectral sensor called Thematic Mapper, the NASA-Ames researchers have imaged more than 24,000 square miles of the northern Yucatan Peninsula. A total of 50,000 square miles will be imaged by 1987. Researchers also are studying the Maya environment in Central Guatemala, Belize and Quintana Roo, Mexico, with SEASAT, a radar-equipped satellite which operated in 1978. SEASAT data was supplied by the National Oceanic and Atmospheric Administration and NASA's Jet Propulsion Laboratory, Pasadena, Calif.

Analysis of Landsat images has shown that ancient Maya settlements in the northern Yucatan were closely concentrated along faults and fracture zones in the Earth. The fracture zones, shallow depressions created by tectonic fault lines in the bedrock, pro-

vide close access to subsurface water and have the best soil in the region. Previously, scientists had believed that topographical features in the flat, densely-forested region were too small and scattered to affect Maya settlement patterns. "We've found a very dramatic difference in resource distribution in what was thought to be a relatively undifferentiated region," said Maya archaeologist Edward Kurjack of Western Illinois University, Macomb, Ill., the principal archaeological collaborator in the project.

In another research area, using SEASAT data, Duller has discovered what appears to be an ancient river plain extending 300 miles across lowland Guatemala. If confirmed by ground-based studies, the finding could explain the location of Tikal, a major Maya trade and ceremonial center from 200 BC to 900 AD. Tikal appears remote and landlocked today.

The dry river plain also would provide evidence of a changing climate which could explain why the Maya abandoned major centers in this region in the 10th century as archaeological findings suggest.



Landsat satellite imagery of the Northern Yucatan Peninsula

A third major focus of investigation is the Yucatan Peninsula's northern coastline. Scholars have long known that the sea level along the Yucatan rose during Maya times, inundating the coast and increasing the salinity of the subsurface water table. The rise in sea level curtailed the important Maya salt trade as the salt flats became submerged, shut down coastal settlements and may have affected agriculture far inland.

Ames researchers have found that the satellite images show natural linear features marking former coastlines beneath the water, enabling mapping and dating of various changes in sea level. Duller and Kevin Pope, a paleoecologist now at Ames, have begun analysis of the coastline changes.

The research also is focused on studying the availability and use of surface water by the Maya. "Water is the key to understanding the Maya," Kurjack says. "Finding sufficient water was an enormous challenge faced by the Maya and studying water resources will help in understanding their agriculture and population distribution."

Satellites can detect major Maya surface water sources, including small, scattered lakes, as well as aguadas, natural pools of water which the Maya often used for water storage, and cenotes, natural wells formed from collapse or erosion of the limestone shelf. Kurjack and Duller plan to study the means of water storage used by the Maya in different regions by mapping the natural opportunities for getting water and overlaying this with a map of archaeological sites.

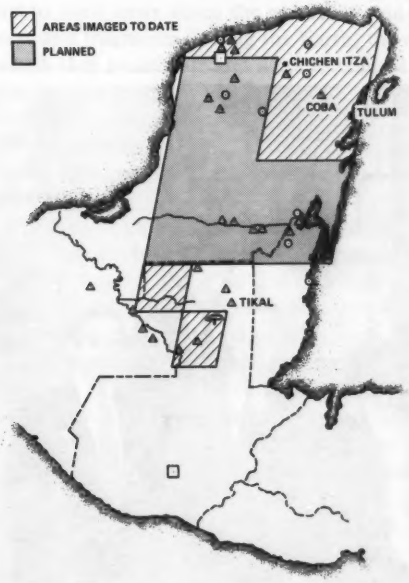
In the Yucatan, which has mainly seasonal surface water, the NASA researchers are comparing imagery from the wet and dry seasons to determine the distribution of surface water. Coupled with ground-based studies of how the climate has changed, the research will lead to a determination of how much water might have been available during Maya times. Scientists could then determine which areas might have been optimal for agriculture and how many people the land could have supported. This could help shed light on the periods of Maya decline.

Some scholars believe the Maya may have exhausted the soil in attempting to support a large population. The Maya are thought to have practiced slash-and-burn farming, which leads to water runoff, erosion and depletion of nutrients, unless the land is allowed to lie fallow for 8 out of 10 years. "They may have severely damaged their environment. Much as we do today, they appear to have sought short-term benefits and created a long-term disaster," Kurjack said.

Researchers believe that locating surface water sources is an effective means of discovering new archaeological sites. "It's closely coupled. Where you find water, you usually find ruins," Duller says. The Landsat images show numerous apparent aguadas and cenotes, which must be confirmed by field investigation.

NASA researchers had initially hoped Landsat would detect ruins directly. They had thought vegetation growing on ruins would be weaker or more stressed, since they have poorer access to water, and thus appear in a different shade in the infrared images from surrounding vegetation. But the researchers found that in the Yucatan all vegetation appears highly stressed. Duller believes that radar

imagery will be able to penetrate the dense vegetation covering many sites. If permission from the Mexican government can be obtained, he would like to use radar-equipped aircraft for further research.



A graph illustrating sections imaged to date

Satellite imagery has been highly effective for locating cleared ruins. This capability is significant because much of the Yucatan is only now being mapped and locating even excavated sites from the ground has been extremely difficult since the region is flat, thickly forested and has few roads. "There were explorers in the Yucatan for a hundred years. Sites were discovered, lost to memory, rediscovered, named and renamed," Kurjack recalls. (Kurjack is now working with the Mexican National Institute of Anthropology and History, in their project to map all archaeological ruins in the Yucatan.)

Ames researchers have mapped large portions of the 62-mile raised road from Coba to Yaxuna, which is by far the longest of the many elaborate causeways built by the Mayas to connect ceremonial centers. Kurjack and Duller now plan to study the environmental setting of the Coba-Yaxuna road, particularly its location in relation to water sources and settlements.

The researchers stress that satellite data is highly valuable in archaeology not just for finding ruins, but for helping to understand the environment and thus, the civilization. "Archaeology is not just a glorified treasure hunt. It is the study of the relationship between human beings and their environment. Satellite technology is an extremely effective and inspiring way for archaeologists to study the environment," Kurjack said.

The Ames archaeology-remote sensing project stems from NASA's interest in demonstrating the applications of space technology to a wide variety of disciplines. The project also reflects NASA's growing emphasis on applying space technology to studying the Earth's ecosystem — the problems involved in maintaining a stable, life-sustaining environment on Earth.

NASA COSPAS/SARSAT Managers Honored By USSR

Two NASA search and rescue mission managers, Robert Lovell and Fred Flatow, were awarded the Yuri Gagarin medal by a space delegation from the Soviet Union.

The Yuri Gagarin medal, named after the Soviet cosmonaut who was the first man in space, was bestowed upon Lovell and Flatow in recognition of their contribution to COSPAS/SARSAT, an international search and rescue program which uses satellites to locate people in distress. Since its inception in 1979, COSPAS/SARSAT has helped save nearly 750 lives.

Robert Lovell

Fred Flatow

The Yuri Gagarin medal is awarded for outstanding achievement in astronautics.

Lovell has worked for NASA for 25 years. Since 1980, he has served as director, Communications Division, NASA Headquarters, Washington, D.C. He manages advanced communications satellite technology research and development.

Flatow joined COSPAS/SARSAT in 1982 as deputy for search and rescue missions, Goddard Space Flight Center, Greenbelt, Md. He became search and rescue missions manager in 1984.

In the United States, COSPAS/SARSAT is jointly operated by NASA, the National Oceanic and Atmospheric Administration, the Coast Guard and the Air Force.

The research and development effort for the U.S. participation in COSPAS/SARSAT is conducted by NASA's Goddard Space Flight Center.

The United States, Canada, France and the Soviet Union are the principal partners in the search and rescue program.

NASA Productivity Officials Meet AT JPL With New NASA Director Of Productivity

On December 8-9, 1986, agency Productivity Focal Point officials attended a workshop at the Jet Propulsion Laboratory with the director and deputy director of the NASA Productivity Programs Office. This was the first meeting of the group under the leadership of C. Robert Nysmith who was appointed director of NASA Productivity Programs earlier in the month. The purpose of the workshop was to develop a strategic plan for the future for the agency's Productivity Improvement and Quality Enhancement (PIQE) Program.

After review of the past and present PIQE status, the group initiated development of a strategic plan for the quality and productivity program throughout the agency. Among projects recommended to be retained were the highly successful NASA Symposiums on Productivity, the last of which attained national recognition for its challenge of our nation's industrial leadership to substantially improve the level of quality of American's goods and services, and the productivity of its workforce.

New projects also were proposed which would be added to the ongoing ones for a continuously progressive program leading to improved quality and productivity in NASA and among its aerospace contractors.

Attendees, left to right, front row: Warren Camp, KSC; Fred Felberg, JPL; Charlotte Marsh, JPL; Ron Carter, NSTL; Barbara Blue, HQ; Charles P. Boyle, GSFC and David Steigman, LeRC. Second row: Bill Williams, LaRC; Gene Guerny, HQ; Dr. Lyn Randolph, HQ; Leo Lunine, JPL; Les Sullivan, JSC and Ray S. Mayfield HQ. Back row: Lewis L. Peach, ARC; C. Robert Nysmith, HQ; Joyce Jarrett, HQ; William R. Reynolds, MSFC; and Dr. Wayne Young, JSc.

Space Debris

(first of two articles)

Since 1976, scientists at the Johnson Space Center, (JSC), Houston, Tx., have been studying orbital debris to learn more about the nature of man-made objects and fragments circling the Earth, the means by which they proliferate and ways to control and protect against the problem.

Rings are forming around the Earth.

"We already have them," said Joe Loftus, JSC's Assistant Director for Plans, "they are just awfully thin."

Rings are not unusual in the Solar System. But Earth's rings are being formed out of man-made orbital debris instead of the natural rocks, dust and ice that encircle other planets. As humans increase their activity in space, they are taking with them one of their most insidious problems - pollution.

There are an estimated 4 million pounds of man-made material in Earth orbit today. Approximately 95 percent of that mass is debris. The current launch rate of Earth's spacefaring nations puts an additional 2 million pounds into orbit each year, and is expected to increase to nearly 3 million pounds a year by the year 2000.

By that time, if current models and forecasts hold true, there will be 10 million pounds of man-made material circling the planet. And those forecasts factor in the material that reenters the atmosphere.

Just as pollution creates immediate and long-term hazards on Earth, debris poses immediate hazards in orbit and has broad implications for the future of space exploration. JSC scientists, among the world's foremost experts on the subject, warn that orbital debris is a growing hazard to space vehicles and that it could have far-reaching effects on launch vehicles, payload design, the Space Station, orbit selection and international relations.

"I don't think you can have a long-term presence of man in orbit without these studies," said Don Kessler, the project scientist for orbital debris studies who has been investigating the problem of both natural and man-made particles in space off and on since 1963. "Today, we're at the threshold of a heightened level of concern because it's making a design difference."

"Understanding orbital debris really is the most important part of trying to maintain a manned space presence," said Burton Cour-Palais, a senior JSC scientist working on the project. "I am personally concerned that we have created a situation that is going to have to be stopped or limited."

Before designs and operations practices can be changed, however, the makeup of debris must be understood, Loftus said. Scientists have had an excellent working knowledge of natural meteoroids for years, but are only beginning to understand man-made orbital debris.

Engineers hold up pieces of metal pierced by projectiles from tests evaluating hypervelocity impact of materials.

Efforts to characterize the orbital debris environment involve optical, radar and infrared measurements, inspections of satellite and spacecraft parts that have been returned to Earth, laboratory experiments with launchers that boost particles to hypervelocity (which begins at about 3 kilometers per second) and computer modeling, Kessler said.

"What kind of stuff is in orbit?" Loftus asked. "Only five percent of it is payloads that are still operating; 21 percent is payloads that no longer are operating; 25 percent is spent stages, miscellaneous pieces of gear; 49 percent of the objects are breakup debris."

A late 1986 "box score" put out by the North American Aerospace Defense Command (NORAD) and NASA's Goddard Space Flight Center listed 6,194 radar-trackable objects — baseball-sized and larger — in space. Of those, 1,582 are payloads, 68 are interplanetary probes, 4,488 are pieces of orbital debris, and 56 are interplanetary probe debris.

In addition to trackable objects, Kessler said, there are about 30,000 marble- to baseball-sized objects, trillions of tiny paint flakes and tens to hundreds of trillions of still smaller aluminum oxide dust-sized particles. During hypervelocity impact events, particles as small as the largest paint flakes can be damaging or lethal.

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The few trackable objects pose a relatively small hazard to spacecraft because they can be tracked using radar and telescopes, and then avoided. The vast numbers of smaller breakup debris particles present a hazard disproportionate to their size because they are "hidden" by the even greater vastness of space.

The first real proof that man-made orbital debris was striking spacecraft was the S-149 particle collection experiment aboard Skylab, Kessler said. The purpose of the experiment was to look for meteoroid impacts, but researchers also found aluminum-lined pits characteristic of man-made debris hypervelocity impacts.

An examination of the Skylab IV command module windows in orbit in 1973-74 also turned up aluminum-lined pits probably caused by collisions with aluminum oxide particles from solid rocket motor exhaust.

Results of the Explorer 46 meteoroid bumper experiment conducted from 1972 to 1975 weren't published until 1983, but they gave researchers two important clues. The experiment showed that the direction of the particles hitting the bumpers was characteristic of an Earth-orbiting population and that the times of the impacts correlated with solid rocket motor firings in space.

A major milestone occurred in 1984, when ground telescope observations that allowed scientists to see marble-sized pieces of debris, turned up eight times as many pieces as had been predicted using the NORAD catalogue alone, Kessler said. At about the same time, the first operational loss of a spacecraft part directly attributable to man-made orbital debris occurred, Kessler said. The crew of STS-7 reported an impact crater on one of *Challenger's* windows, and the damage was significant enough that the window had to be replaced after landing.

Within weeks of the STS-7 incident, the Soviet's Salyut 7 reported a similar window impact. The crew of that craft reported actually hearing the impact, Kessler said.

In April 1984, astronauts repaired the Solar Maximum Mission satellite in orbit during STS 41-C and returned to Earth with 15 square feet of the satellite's insulation blanket and 10 square feet of aluminum louvers that had been exposed to space for 50 months. JSC scientists found many more pits and holes than expected — thousands of pits, and 32 holes per square foot in the insulation and 6 holes per square foot in the louvers. Chemical analysis of the pits showed most were caused by collisions with paint flakes.

Launch operations, explosion of propellants remaining aboard spent rocket stages, collision with other pieces of orbital debris or some combination of factors are the most common creators of orbital debris. Collisions, however, are of particular interest to debris investigators because of the extremely high relative speeds of objects in orbit.

"In a collision, where you have a 10-pound mass hit a 1,000-pound stage, you multiply 10 times 25,000 feet per second squared and there's an enormous amount of energy," Loftus said. "Such an event creates 4 million particles and 10,000 bigger pieces. That's why the collision event is so significant."

"We have been developing techniques to determine if breakups are caused by explosion or collision," Kessler said. "That's important for two reasons. One, if it was caused by an explosion there are fewer small fragments generally and it's fixable by the person that launched it (in terms of preventing future events). Two, if it was caused by a collision it produces more small fragments and increases the hazard and means the space community soon must set policies not to allow this to happen."

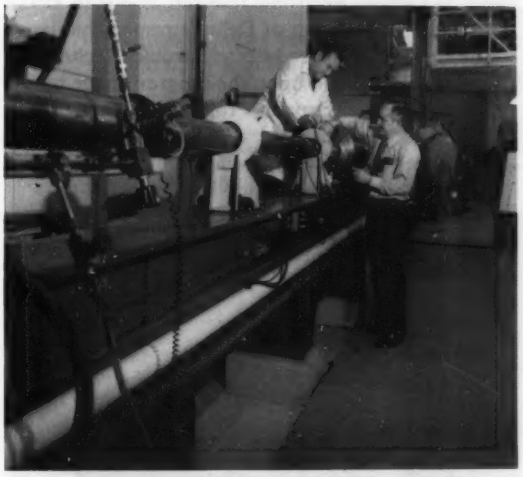
One significant contributor to orbital debris was a series of seven Delta rocket second stage breakups. Investigators determined that the cause of the breakups, some of which occurred as much as three years after launch, were exploding unspent hypergolic fuels. Changes in Delta launch procedures, suggested by JSC scientists, were instituted in 1981 and appear to have solved the problem.

One of the most recent breakups in orbit was in November 1986, when a 9-month-old Ariane third stage booster broke up. About 460 fragments of the spent stage are being tracked so far, Kessler said. Most appear to be less than a square meter in size, but the size range has not been determined. The debris is in a roughly polar sun-synchronous orbit at 98.70 degrees. The force of the breakup threw debris into orbits as low as 400 kilometers and as high as 1400 kilometers. JSC scientist have been working with European scientists involved in the Ariane program to help determine the cause of the November 13, 1986, breakup. Space Sciences Branch Chief Drew Potter, and scientists Karl Henize, Faith Vilas and John Stanley have been using the opportunity to take optical and infrared measurements of the fresh debris.

Astronomical observers of debris have three main objectives, Vilas said. First, they are trying to learn more about the size, altitude and distributon of particles in low-Earth orbit. Next, they are trying to

determine the visual and infrared reflectively and other observable characteristics of debris to verify or modify existing models. And, she said, they are just beginning to develop a collision warning system for the Space Station.

Whatever the cause, breakups significantly increase the number of pieces circling the globe, which is one of the reasons collisions are expected to become more frequent. And that makes the location of debris in orbit another important part of the information JSC's scientists have been working on, Loftus said.



Engineers load a projectile into NASA's 'light gas gun.' Projectiles are launched at speeds up to 26,000 feet per second at sheets of metal, analyzing how future spacecraft might be affected by space debris and micrometeroids

"Not only are things not evenly distributed in inclination, they are not uniformly distributed in altitude," he explained. Below about 500 kilometers, atmospheric drag causes most objects to reenter. "Eight hundred kilometers is sun-synchronous altitude so you see a big peak there, and then it rapidly falls off to 2,500 kilometers and then there is a big peak at geosynchronous altitudes. In between, relatively little."

JSC scientists are using the knowledge they gain about debris to make computer models that can predict the probability of debris-spacecraft collisions. These probabilities are in turn being used to investigate possible protective measures.

"What we've been doing for the last 10 years for all intents and purposes is trying to understand what the real environment is by making more radar measurements, by making optical measurements, by examining things that we get back from space like the thermal panel from the Solar Max, and gradually we are getting more knowledge about what is there," Loftus said. "We are embarking on a series of studies to find out what various protective and preventive measures cost. We don't know the answer to that yet."

NEXT ISSUE: IMPACT AT HYPERVELOCITY

NASA's Robert Bruce Named Federal Employee Of The Year

NASA's Robert Bruce, project manager in the Facilities Engineering Office at the National Space Technology Laboratories, is one of two Gulf Coast residents named 1986 Federal Employee of the Year. Bruce shares the honor as co-winner with Thomas Graham, a training specialist at Keesler Air Force Base.

The annual award is sponsored by the Mississippi Coast Association of Federal Administrators to recognize an outstanding federal employee on the Gulf Coast.

Bruce serves as project manager in the Test Support Management Branch and was cited for managing "the most significant modification project to be accomplished at NSTL in recent years." The $7 million project involves the modification of the B-1 test stand which was built for testing the first stage of the Saturn V space vehicle in the 1960s. The modified stand will give NSTL a third capability to static-fire Space Shuttle main engineers individually.

NASA's nomination of Bruce stated, "The fact that he has been assigned to manage this complex project which utilizes both NASA and contractor manpower is evidence of the high degree of esteem and respect which his superiors and peers have for him."

Bruce has worked for NASA at NSTL for the past 3 years and during that time has been honored for outstanding performance in Space Shuttle facilities engineering. He previously worked for Pan Am's Shuttle Projects Division at NSTL.

A 1974 graduate of the U.S. Naval Academy, Bruce has a bachelor's degree in aerospace engineering and also earned a master's in engineering management from Tulane University.

Robert Bruce (right) accepts his award

He serves in the U.S. Naval Reserve as a lieutenant commander and was recently named commander of a reserve unit stationed aboard the USS John Hancock based at Charleston, S.C.

In addition to his professional accomplishments, Bruce was cited for being "highly committed to the education and encouragement of children to grow into useful civic-minded citizens." As a board member of the Bayou View Elementary School PTA in Gulfport, he reinstituted the annual science fair in which more than 130 students participated. Most recently he served as chairman of the computer purchasing committee, recommending computer systems for the PTA-provided computer lab.

New Microdevices Facility Planned For Jet Propulsion Laboratory

NASA's Jet Propulsion Laboratory, Pasadena, Calif., broke ground for a new Microdevices Laboratory January 21, 1987.

On the same day, a memorandum of understanding was signed by NASA Administrator Dr. James Fletcher and Dr. Marvin Goldberger, President of the California Institute of Technology (Caltech), establishing the Center for Space Microelectronics Technology, which will be housed in the Laboratory at JPL.

The Center will provide long-range supporting research and development in advanced microelectronics for a wide range of U.S. space-related efforts. "The Center for Space Microelectronics will make JPL a national center for excellence in selected parts of space microelectronics," Allen said.

JPL is a division of Caltech, operated for NASA. Caltech faculty collaboration will be a principal feature of the Center for Space Microelectronics Technology.

At the request of Dr. Burton Edelson, NASA Associate Administrator for Space Science and Applications, NASA, in July 1983, JPL established the Advanced Microelectronics Program under the direction of Dr. Carl Kukkonen to emphasize computational and device electronic research unique to JPL, NASA and Department of Defense responsibilities.

The Center for Space Microelectronics Technology will replace and build upon the progress made by the Advanced Microelectronics Program. Kukkonen will be the center director.

Highlights of the JPL Advanced Microelectronics Program during 1986 included fabrication of a super conducting tunnel junction detector for submillimeter wave astronomy.

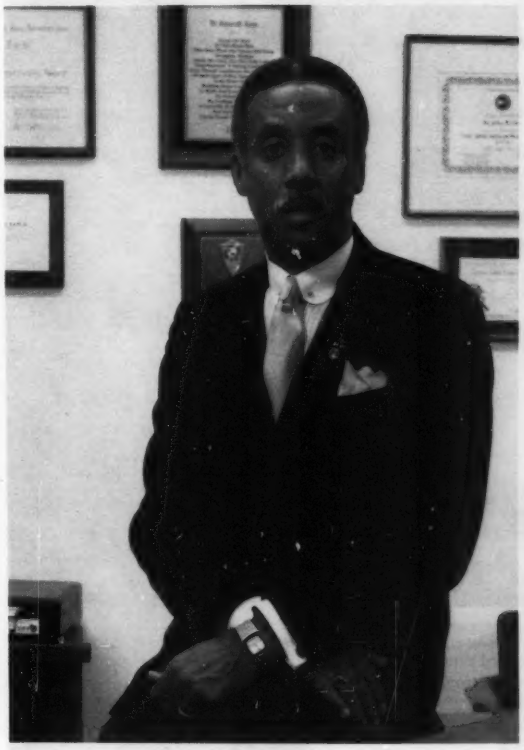
NASA officials break ground for the new facility

The Center for Space Microelectronics Technology will be directed by a Board of Governors chaired by Dr. Allen. Other members of the board include Goldberger; Dr. Edelson; Dr. Ray Colladay, NASA Associate Administrator, Office of Aeronautics and Space Technology, NASA and Dr. James Ionson, Director of the Innovative Science & Technology Office, Strategic Defense Initiative Organization.

NASA Lewis Manager Julian Earls Elected To College Hall of Fame

NASA Lewis Research Center Division Chief Dr. Julian M. Earls was selected to be among the first group of distinguished blacks voted into the National Black College Alumni Hall of Fame at an Atlanta University ceremony.

Dr. Earls was inducted into the Hall of Fame along with the late Dr. Martin Luther King, Jr., U.S. Supreme Court Justice Thurgood Marshall, Metropolitan Opera star Leontyne Price, past Morehouse University president the late Benjamin E. Mays, Atlanta businessman Herman J. Russell and Grambling University football coach Eddie Robinson.



As chief of the Health, Safety, and Security Division, Dr. Earls manages over 150 personnel in areas comprising occupational medicine, environmental health, radiation physics, industrial safety and physical classified and computer security. He began his managerial career with Lewis at age 25, becoming one of the youngest managers in the history of the space agency at that time.

Widely recognized as an expert in health physics and as a humanitarian, Dr. Earls is rapidly gaining a national reputation as a lecturer and keynote speaker. In 1986 he delivered the commencement addresses at the University of California's College of Engineering and Kentucky State University.

Dr. Earls has delivered lectures at Syracuse and Northern Michigan Universities as well as Rensselaer Polytechnic Institute and twice at Massachusetts Institute of Technology. He has been selected to be the 1987 Distinguished Scholar Lecturer at Western Illinois University. He was the keynote speaker at a Governors Reception in St. Thomas, Virgin Islands in 1983.

The major thrust of Earls' humanitarian efforts involved forming a national organization to provide scholarships for black students who choose technical majors at historically black colleges. Started in 1983, the Development Fund for Black Students in Science and Technology is supporting students at three universities. Members across the country pledge $1,000 a year for the rest of their lives in hopes of establishing a $1 million endowment fund for the scholarships.

The Portsmouth, Virginia native earned a bachelor's degree in physics from Norfolk State University; a masters in physics from the University of Rochester; a masters in environmental science and a Ph.D. in physics from the University of Michigan. He also is a graduate of the Harvard University Graduate School of Business Administration.

Earls and his wife, Zenobia, of Beachwood, Ohio, are the parents of two sons. Julian, a Howard University graduate, is a medical student at Case Western Reserve University. Gregory is a student at Norfolk State University.

An avid runner, Dr. Earls has successfully completed the Boston Marathon twice.

Did You Know?

NASA and the Royal Moroccan Air Force concluded an agreement under which Morocco will permit the use of Ben Guerir Air Force Base as an emergency landing site for the U.S. Space Shuttle.

The agreement, under discussion since early summer of 1986, provides for an emergency recovery

location for the Space Shuttle in the event of certain contingencies during launch phase of missions originating from the Kennedy Space Center, Fla.

The agreement was signed by NASA Administrator Dr. James C. Fletcher and Moroccan General Kabbaj, the Inspector of the Royal Moroccan Air Force.

Under the agreement, the coordinating agencies will be responsible for carrying out the terms of the relationship. Activities are currently underway to make the facility ready for renewal of Space Shuttle launch activity in February 1988.

NASA EO Trophy Won By Goddard

The Goddard Space Flight Center (GSFC), Greenbelt, Md., for the second time, won the NASA Equal Opportunity Trophy for its affirmative action accomplishments during FY 1986. GSFC received the first trophy which was awarded in 1931. Pictured is NASA Administrator Dr. James Fletcher congratulating GSFC director Noel Hinners.

The trophy recognizes the NASA installation and management team which has implemented the most effective management strategies and has achieved the most positive affirmative action results.

During FY 1986, GSFC was particularly exemplary in its net increase of minorities and women in all code blocks and in science and engineering managerial/supervisory jobs; in professional administrative hires at managerial and non-supervisory levels; in minority and female business; in feeder programs such as its new Public Service Intern Program; and in numerous other management strategies.

Along with the trophy GSFC also received a monetary award of $10,000. The center plans to use that money to enhance the work opportunities for handicapped individuals. Prizes will be provided for the best employee suggestions and innovative ideas for devices or processes which will facilitate handicapped employees in their work life. Additionally, eight handicapped students will be selected for six-weeks of summer employment.

Two additional centers, the Johnson Space Center and the Kennedy Space Center, were runners-up for the EO Trophy Award and were commended for their excellent records of attaining the goals that they set for themselves and for making significant gains in many areas

The EO Trophy which will remain at GSFC for one year

Twenty-four students from Cooperating Hampton Roads Organization for Minorities in Engineering (CHROME) tackled the challenge of flight at the NASA Langley Visitor Center on December 29-30, 1986.

These students from area schools were selected by essay competition. Their essays were entitled, "Why I want to attend the NASA Aero-Space Camp."

Activities for the 2-day camp included a visit to NASA's structures laboratory for a demonstration of new materials for subsonic flight and a look at computer-assisted aircraft designs. The students also toured the 14 x 22-foot wind tunnel.

Students building scale models of the X-29 experimental aircraft under the direction of NASA model maker Tom Vranas

NASA research engineer Frank Quinto explains critical displays in the control room of the 14- x 22-ft. wind tunnel at the Langley Research Center

Highlighting camp activities was the model-making session directed by NASA model maker Tom Vranas. After building scale models of the X-29 experimental aircraft, students flew their craft, calculating linear distance, altitude and soaring time.

Founded in 1983, CHROME is a non-profit partnership of public and private employers, secondary and higher education, civic and professional organizations that recognize the need to identify, counsel and nurture socially and economically disadvantaged students who demonstrate a potential for becoming engineers, scientists, or specialists in high technology.

Sponsors of CHROME include Ford Motor Company, NASA, Newport News Shipbuilding, Systems Management American Corporation, C & P Telephone, Old Dominion University, Norfolk State University, and Hampton University.

Contractor News

NASA's Marshall Space Flight Center, Huntsville, Ala., selected **Computer Sciences Corp./Pan Am World Services,** Falls Church, VA. for negotiations leading to award of a 10-year contract to operate a space agency computer facility.

The contract will call for the management, operation, maintenance and protection of Marshall's Slidell Computer Complex, Slidell, La. The facility provides computer services support primarily to Marshall's Michoud Assembly Facility, New Orleans, which manufactures external tanks for the Space Shuttle.

The company will provide the necessary personnel, equipment and supplies to carry out its duties. The contract has an initial period of performance of 1 year, beginning in February 1987, and will contain nine 1-year options. The approximate, proposed value of the 10-year contract will be $99 million.

NASA's John F. Kennedy Space Center, Fla., awarded **EG&G Florida, Inc.,** Cocoa, Fla., a 1-year, $129.3 million extension to its existing contract for base operations services.

The extension covers the period of Jan. 1 through Dec. 31, 1987, and brings the total value of the contract to $565.3 million. This is the fifth 1-year extension to the Base Operations Contract awarded EG&G in January 1983.

EG&G Florida, Inc. is part of the Government Services Division of EG&G, Inc., based in Wellesley, Mass.

Under the extension, EG&G will continue to provide institutional and technical support services such as utilities, facilities, administrative services, technical operations and health and protective services at the Kennedy Space Center.

NASA Lewis Research Center, Cleveland, Ohio awarded an $11 million contract to **General Dynamics Corp., Space Systems Division,** San Diego, Calif., to erect, test and launch Atlas/Centaur vehicles at the Eastern Missile and Space Center, Fla. The launch vehicles will carry Fleet Satellite Communications spacecraft, a Department of Defense satellite.

The cost-plus-award-fee follow-on contract with General Dynamics, began January 5, 1987 and ends December 31, 1987, unless the launch period is extended.

Centaur is a high-energy, upper stage using hydrogen/oxygen cryogenic propellants. The Atlas/Centaur combination has launched many large payloads, including a variety of scientific missions and domestic and military communications satellites to geosynchronous Earth orbit.

NASA's Ames Research Center, Mountain View, Calif., selected **Federal Systems Division,** Northern Telecom, Inc., Vienna, Va., for final negotiations leading to the award of a firm-fixed-price contract. The contract has a proposed value of approximately $20 million for the first 5 years.

The contract will provide options to extend the contract, in 1-year periods, for maintenance, operations and system expansion for a total performance period of up to 10 years.

NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., selected the **Bendix Field Engineering Corporation** (BFEC), Columbia, Md., for negotiations leading to an award of a contract for continuation of maintenance and operations of the NASA Deep Space Network (DSN).

The new, cost-plus-award-fee contract will cover a period of 5 years with provisions for an additional 5 years of options. The contractor's estimated value of the contract is approximately $139 million. Following negotiations, the new contract began April 2, 1987.

The DNS is operated by JPL to provide tracking and data acquisition support for planetary spaceflight missions and for NASA's manned and unmanned space programs.

Work will be performed at JPL and at the Goldstone complex and Barstow facility in the Mojave Desert of California.

BFEC is a technical services unit of Bendix Aerospace Sector of Allied-Signal Inc.

NASA Langley Research Center, Hampton, Va., selected the **ST Systems Corp.,** Lanham, Md., to provide support services for atmospheric science research at the Langley center.

The cost-plus-award-fee contract has an estimated value of $32 million and covers a total period of 5 years (2 years plus three 1-year options). The contract period began April 1, 1987.

ST Systems, formerly SASC Technologies Inc., will support Langley's Atmospheric Sciences Division in measuring, analyzing and modeling Earth's atmospheric processes to better understand couplied chemical and physical properties over a spatial range from cloud to planetary scale and a temporal range from minutes to decades. Information for quantitative analysis is acquired through field research, in addition to laboratory, aircraft and spacecraft.

The company will support Langley researchers through analytical studies, processing and storing operational data, developing measurement instruments, spectra analysis, mission planning and documentation.

Another Dividend from Air and Space

Research and development in aeronautics and space have provided numerous benefits for all Americans—and at a tiny percentage of the tax dollar. Here is an example:

Spinoff From The Moon Boot

The Apollo lunar suit worn by a dozen moonwalking astronauts was a masterpiece of design and engineering, a complex space system that included a built-in artificial atmosphere for breathing and pressurization, protection against temperature extremes, micrometeoroid shielding, eye protection against blinding glare and a score of other features intended to assure lunar mobility with safety and comfort. One little-known feature was use of a special three-dimensional "spacer" material in the lunar suit's boots for cushioning and ventilation. That material has turned up, in modified form, as the key element of a new family of athletic shoes designed for improved shock absorption, energy return and reduced foot fatigue.

Manufactured by KangaROOS USA, Inc., St. Louis, Missouri, the new line of shoes resulted from a 2-year research and development program. The company sought to reduce athletic impact forces, which are transferred by the muscular-skeletal system through the foot and lower leg, and at the same time provide "medio lateral control" or lateral stability. The problem was that the two functions were inversely related if conventional design techniques were employed, improving one would work to the disadvantage of the other.

The development effort involved KangaROOS High Performance Development Division, aided by consultants, and used as an informational base a study performed by NASA's Aerospace Research Applications Center, Indianapolis, Indiana. From this effort emerged the Dynacoil athletic shoe cushioning system, featuring a departure from conventional design that, says the company, not only reduces impact shock and provides the requisite lateral stability, but also contributes to increased athletic efficiency.

The mechanical core of the cushioning system is "Tri-Lock" three-dimensional space fabric; an advancement of the original lunar boot material, the woven fiber fabric includes a series of fiber coils as the third dimension. In the KangaROOS Dynacoil midsole design, the space fabric is encapsulated within a polyurethane foam carrier, which in turn is surrounded by a stable "motion control rim."

This design produces a cushioning system that loses virtually none of its shock-absorbing capabilities throughout the life of the shoe. The Dynacoil midsole attenuates the pounding that accompanies running and court sports by virtue of the fact that the waves of interlocking fibers engineered into the space fabric spread the impact of foot strike over a longer time interval, greatly reducing impact forces. In addition, the midsole's exceptional resiliency helps cycle energy back into the athletic.

*NASA does not endorse commercial products developed as a result of its Technology Utilization or Patent Licensing Programs, but it does encourage the widest possible use of its technology.